MIM-3 Nike Ajax, MIM-14 Nike Hercules CIM-10 BOMARC

The road to first SAMs, post WW II threats

The first surface to air missile systems (SAM) entered in service in mid ‘50s both in USA and the Soviet Union. The demand for SAMs was raised by the appearance the high and fast flying intercontinental bombers with nuclear and later thermonuclear bombs. In post-World War II era in early-mid ‘50s cruising speed of bombers reached about 800-900 km/h and their max speed was slightly above 1000 km/h their combat ceiling was about 12 km.

The flight performance of bombers literally made impossible to destroy them with very large caliber (>100 mm) anti-aircraft artillery (AAA) even with proximity fuse (which was available only for US.) Not only the task was harder but the firepower of bombers with nuclear weapons became so big which meant only some bombers were enough to destroy very large cities with some nuclear (20-200 kt yield) or only with a single thermonuclear bomb (2-8 Mt yield).

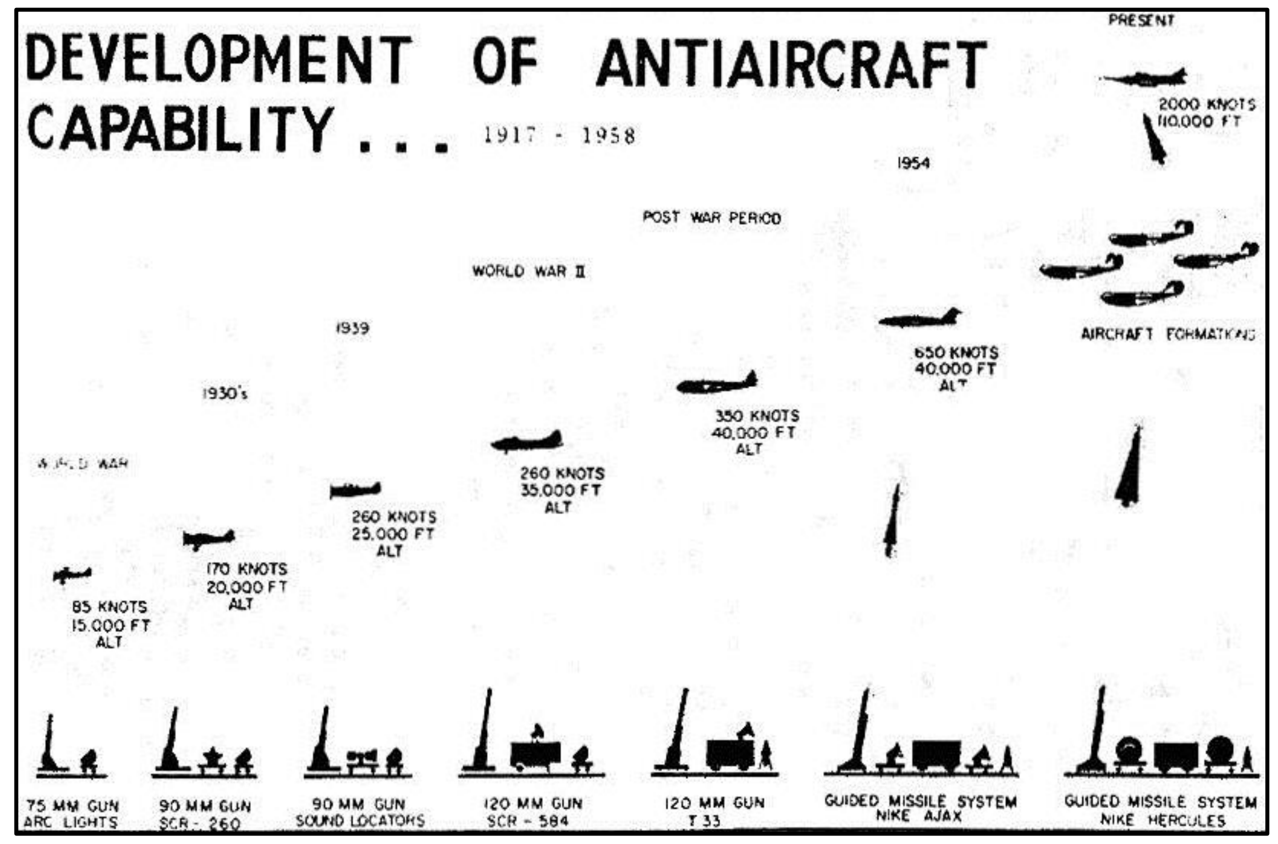
During WW II the US strategic bombing campaign would not was sustainable if the losses were at least 5 percent for a longer period which made sense use AAA guns on some level to cause small but more or less constant damage and losses to bombers. This loss ratio was totally unacceptable against nuclear bombers. Of course loss rate is higher if 1-2 bombers are downed from a half a dozen size “pack” but is harder to shot down a very few bombers with AAA which do not fly in tight formation because only conventional bomb attack required to keep such formation with nuclear bombs such formation is not necessary.

During WW II in Battle of Britain (1940) the heavy AAA fired 49 000 shells and only 12 bombers were downed (and lots of them were damaged) about 4000 shells required to down a single aircraft. Germany achieved a bit better accuracy with radar aided AAA guns in later stages of war about 2900 shells were required for down a B-17 or a B-24 bomber which flew less than 400 km/h speed and only at 6-8 km altitude.

Comparing to WW II piston engine powered bombers the post WW II jet engine powered bombers (B-47, B-52) flew faster ˙(800-1000 km/h) and higher (12 km) through the barrage area of AAA which meant with same fire rate the chance for kill was even lower because of less fired shells and bigger scatter. A bomber flying at 12 km altitude with 800-1000 km/h speed can release its bomb about 8-10 km from the target. This means engaging bombers with anti-aircraft artillery had to start least 25-30 km from the target and AAA guns had to be deployed in large quantity; hundreds were needed to shot down a single bomber.

Considering a Moscow size city building an AAA ring around a city would require technically “infinite” quantity of AAA guns to be able to down only a very few bombers. Defending cities with anti-aircraft artillery became virtually impossible against jet powered intercontinental bombers if they used nuclear bombs. (Of course fighters can shoot down incoming bombers but as last line of defense the anti-aircraft artillery became useless.)

In short the SAM was needed for a much higher kill probability because of speed, altitude and firepower of incoming bombers with nuclear weapons. A single SAM battery offered about 30 km large engagement zone up to 15-20 km comparing to AAA which about 10-12 km or less range and maximal altitude. For a single kill thousands of shells would be needed while in ideal case 1 guided missile potentially could down a 1 aircraft.



Above is the increasing target speed and altitude from WWI to post WWII era. The 2000 kts speed was an over estimated prediction in USSR even M2.0 capable intercontinental bomber was not developed.

The examples above concerned only about heavy AAA such as the famous Flak 36 with 88 mm caliber in WW II. Against maneuvering fighter size targets such heavy AAA were ineffective because their aiming method only small caliber machine guns (12.7 mm) and AAA guns up to 30-40 mm caliber could be used. These had only 1-4 km range up to 2 km altitude which meant army air defense did not have any chance to stop strike fighters or medium size tactical bombers such as Il-28 with nuclear bombs.

In case of conventional weapons fighters and tactical bombers had to fly at low but with nuclear weapons only fighter could shot down the attackers. A bomb released at 4-5 km altitude had hundreds of meters circular error probable (CEP)[1] bit it was enough accurate to deliver a 20-100 kt yield tactical bomb.

In 1944 the Chief of Staff specified the demand for a SAM the Bell Labs company got the task for design which in that time leading in developing radar, radio and remote control technology. The task was creating such system which can deal bombers with 800 km/h between 6-18 km altitudes. In May of 1945 Bell responded the task seemed feasible.

The engineers of the Bell proposed a system with vertically launched two stage missile; the booster stage was solid fuel propelled the second (traveling) stage was liquid fuel propelled. The missile had radio controlled guidance (RCG) which guided the missile towards the intercept point where the warhead was remotely detonated by the guidance station (missile did not have proximity fuse). The radar of the system tracked both the target and missile. In short one of the first concept of and RCG guided SAM system was born which leaded to MIM-3 Nike Ajax and later MIM-14 Nike Hercules systems.

[1] https://en.wikipedia.org/wiki/Circular_error_probable

The first attempt to develop SAMs was during World War II in Germany.[2] As in many cases people tend to overestimate the possible outcome of any German "wonder weapon" plans and ideas. The USA initiated the first SAM program at the end of WW II and only 10 years later produced a weapon system in service. The Soviet Berkut also needed huge resources and 4 years. Similar resources and time were not available for Germany in WW II. Even if they had had time to develop such working system it would not resulted a different outcome because with low level fighter strikes and jamming also would be an option for Allied forces.

The first generation SAMs – both in US and USSR – used RCG guidance any other guidance method was out of option. Infrared guidance did not exist in that time and did not provide the necessary range against bombers. Both Nike systems and the S-25 Berkut (SA-1), SA-75/S-75 Dvina/Volkhov (SA-2) and S-125 Neva (SA-3) used RCG. Luckily the Berkut and Nike systems never saw real combat as it would mean nuclear war.

MIM-3 Nike Ajax

The Nike Ajax had 55 km maximal engagement range up to 21 km altitude maximal speed of the missile was about M2.3; the missile had conventional warhead. One SAM site has one target channel and one missile channel it could engage only a single target with a single missile.

The USA until the overflight mission of U-2 did not have exact information about size of intercontinental bomber fleet ("Bomber Gap") of USSR therefore the SAM defense capability was oversized comparing to threat. The goal was not to defeat only with SAMs the incoming bombers the SAMs just acted as last line of defense to protect the most important large cities of USA. If USSR had dispersed it bomber force among more targets we can say each city would had strong SAM defense even without fighters.

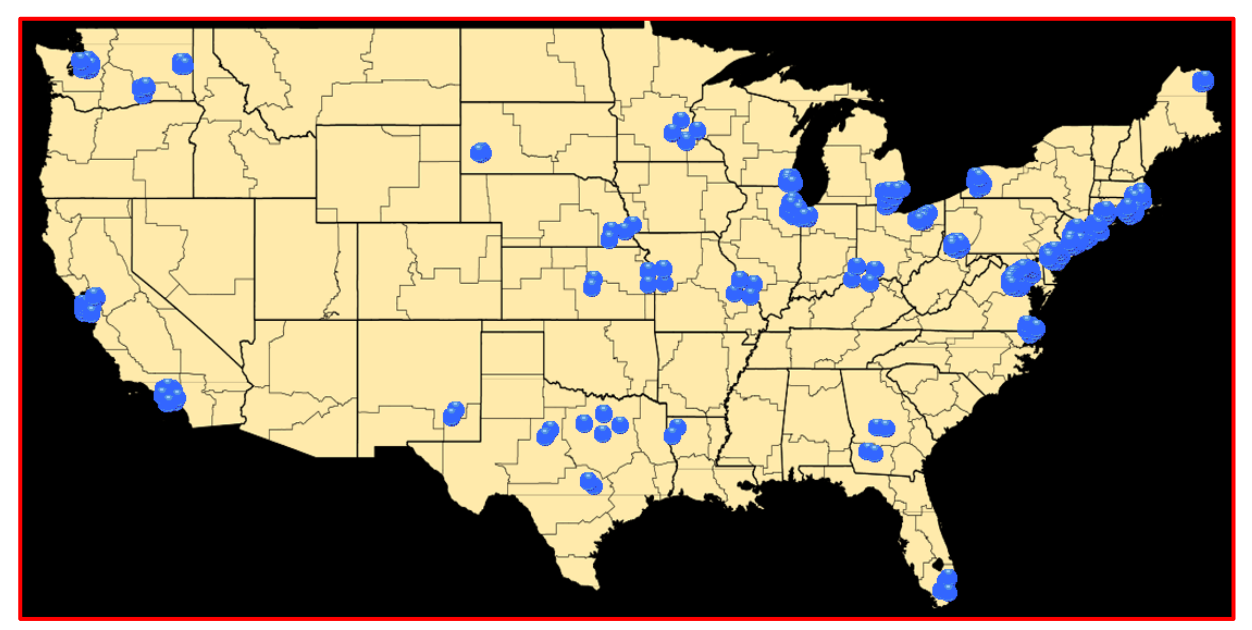
In USA the locations of Nike Ajax sites were the followings, the numbers in brackets show the number of SAM sites: [3]

From 1954	Baltimore (7), Chicago (22), New York (19), Philadelphia (12), San Francisco (12), Washington (13)
From 1955	Boston (12), Detroit (15), Hanford (4), Los Angeles (16), Milwaukee (8), Niagara Falls (4) Norfolk (9), Pittsburgh (12), Seattle (11).
From 1956	Bridgeport (6), Buffalo (4), Cleveland (8), Fairchild AFB (4), Hartford (6), Providence (7).
1957	Ellsworth AFB (4), Loring AFB (4), Travis AFB (4)

In the USA eventually about 225 SAM site were installed in Europe only 24 sites but because of the "Bomber Gap" much more were manufactured. Besides the 250 installed sites equipment of 103 further Nike Ajax sites were put into storage when the real size of the USSR bomber fleet became known. Manufacturing the equipment of 350 sites and 14 000 (!) missile needed only 3 years. We can imagine from these figures how expensive the program was...

As I can judge most of the people have no idea about how serious the SAM programs were in USA. The Russian SAMs systems simply "outshine" the US made types because Nike system never saw real combat while the Soviet SAM many times were used in many wars (both PVO and army air defense systems) sometimes very successfully for example against U-2 in 1st of May 1960.

[2] *https://www.youtube.com/watch?v=B7Q92V5hK-c*
[3] *Rings of Supersonic Steel, chapter 2.*



Nike Ajax sites in USA

Nike Ajax was different from Russian conception, not every site was the same the available missile quantity was determined by the defended target. Eventually the Ajax system declared insufficient to stop a massive Soviet bomber strike this leaded to developing and upgraded version the Nike Hercules. The last Nike Ajax was dismantled in 1964 just after 7 years the last installed Ajax site. This was not rare during the early phase of Cold War many very expensive weapon systems became outdated very quickly.



Nike Missile Base BA-79, Maryland[4]

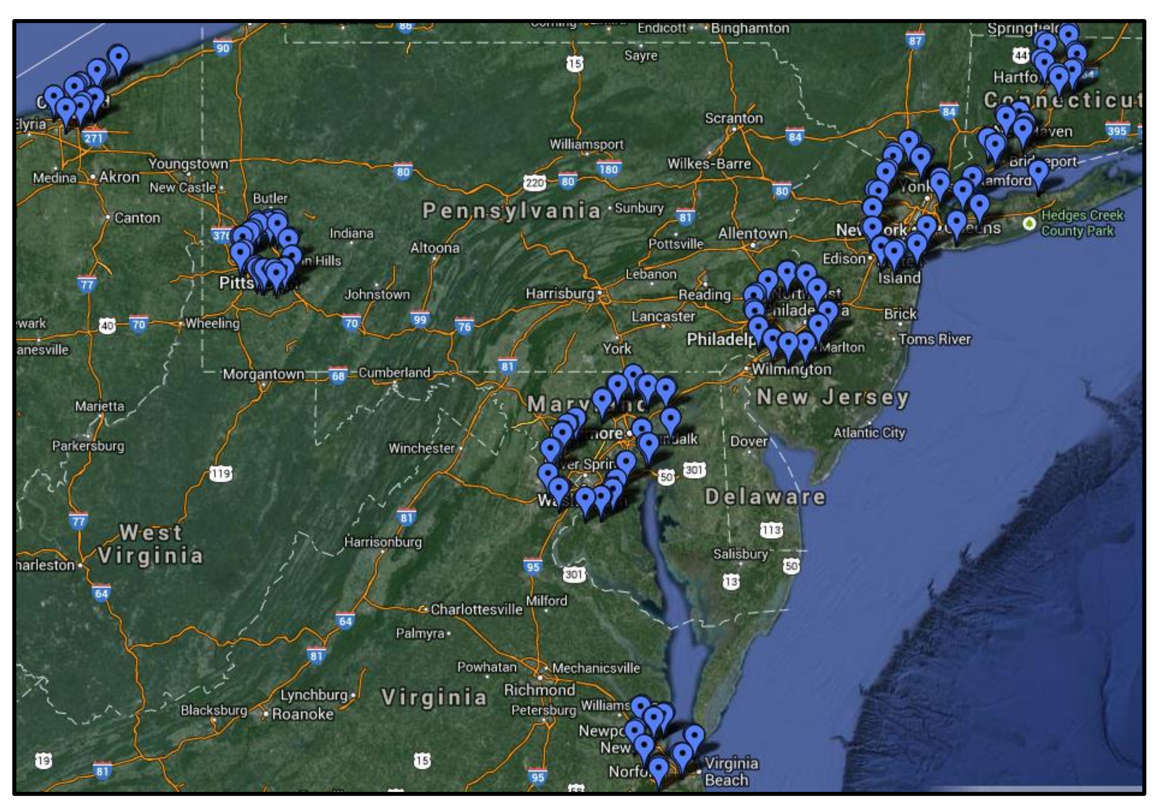
[4] http://www.themilitarystandard.com/missile/nike/ba79.php

MIM-14 Nike Hercules

The Nike Hercules was not a totally new system it used some of the existing items of the Nike Ajax. Because the better performance and capability the Hercules it did not replaced the Ajax with 1:1 ratio. The Nike Hercules was installed in many countries outside US such as Germany, Netherland, Belgium, Italy, Greece, Turkey, South-Korea and Taiwan. Even all of Nike Hercules sites were scrapped in US until 1975 in some countries used them exceptionally long Italy and Turkey phased out only after 2000.[5]

The new missile got the booster stages of the previous Ajax system but instead one now it had 4 solid booster rockets. The engagement range increased to 90 km up to 30 km altitude but the maximal engagement range could be achieved only with nuclear warhead above 55 km range because of the guidance accuracy limitation of RCG method. For testing and training it had conventional warhead but in combat all missile would use nuclear warhead. (This is so strange why so long used both Italy and Turkey because the nuclear warheads were supplied by the USA they never were nuclear powers.) For the larger engagement zone the system got changes in both target acquisition and fire control radars.

We can say with some over statement the upgrading Ajax to the Hercules system was almost like upgrading the SA-75 Dvina to S-200A Angara. (The nuclear warhead made easier the task S-200 used SARH guidance which did made mandatory the nuclear warhead at long range engagement.) Regardless of the much larger engagement range the Hercules remained on the same level considering target channels and missiles channels only one target could be engaged with a single missile.



Nike sites around east coast cities

Target channel means how many targets could be engaged in the same time, missile channel means how many rockets can be guided in the same time. Nike had 1 target and 1 missile channel while the Soviet SA-75 Dvina had 1 target and 3 missile channels so more than one missile could be guided but only on the same target, the later S-300PT (SA-10A) had 6 target and 12 missile channels.

[5] https://www.youtube.com/watch?v=V67WkcqN6MY

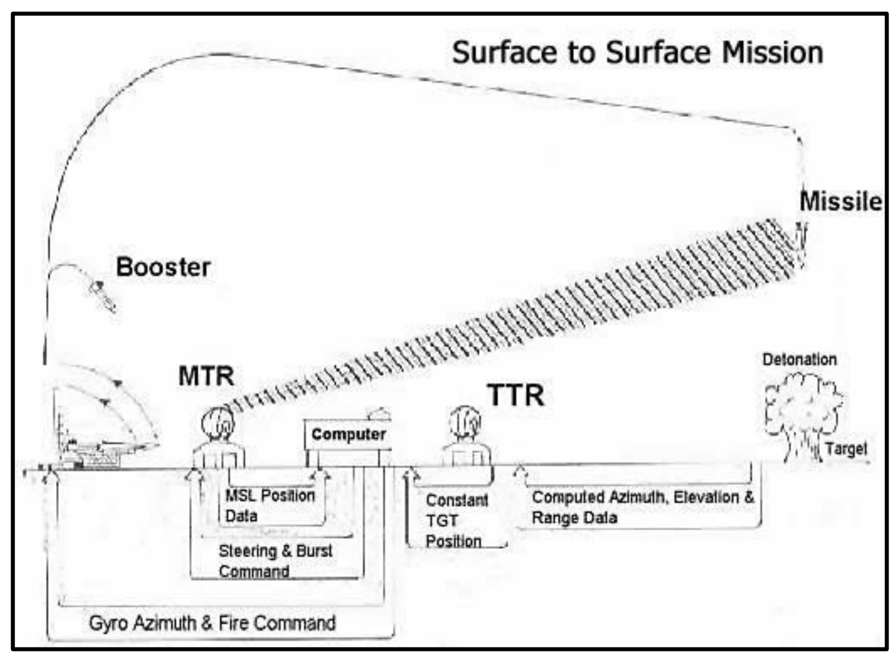
The launch method of Nike Hercules was different from Soviet method of S-75/125/200 where missile rails could be turned to the target. Missile always launched vertical and flew the same path in the climbing phase ensuring the boosting stages land in the same location every time. Because the launch profile and initial development goals – high flying intercontinental bombers were targets – the system had restricted engagement zone against low level targets. The basic version of the Nike Hercules was installed between 1958 and 1962.

The improved version of Nike Hercules arrived in 1961 against electronic jamming got additional radar (TTR) with dm wavelength for target distance measuring. In case of jamming this extra radar provided for short time intervals the distance measuring. (The S-75 had for the same role the Amazonka radar, the conception was the same.) The Nike Hercules fire control radar was monopulse radar which made one of the most advanced radar in that time it was much more jam resistant comparing to older types of radars.[6]

The last version of the Hercules had anti-ballistic missile capability (ABM) but only against "Scud A" type or similar ballistic missiles for this ABM role got the HIPAR radar (with 10 MW peak impulse power). The "Scud" rocket had about M3 speed which meant against ICBMs the Hercules did not have any used but M3 speed ballistic missiles has only about 150 km range. In Europe also was questionable this level ABM of capability because if the troops of WPACT were so close to any of Hercules site it would meant very likely the NATO already has lost the war.

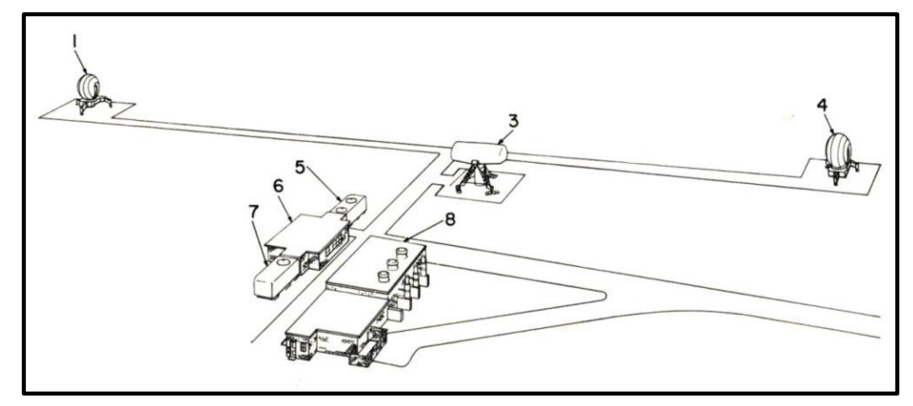
The engagement range of the improved Nike Hercules reached 140 km and could be used against ground targets up to 180 km is emergency case. Of course this capability also would have only limited use even in Europe.

In Europe the HIPAR had peacetime restrictions because disrupted the civilian telecommunications, see the image among the attachments. The plates on the control panel some control buttons were blocked/disabled.

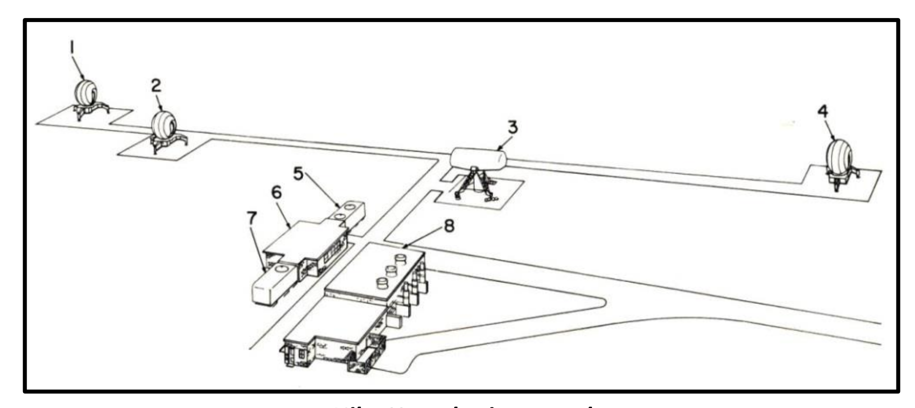


Nike Hercules could engage ground target.[7]

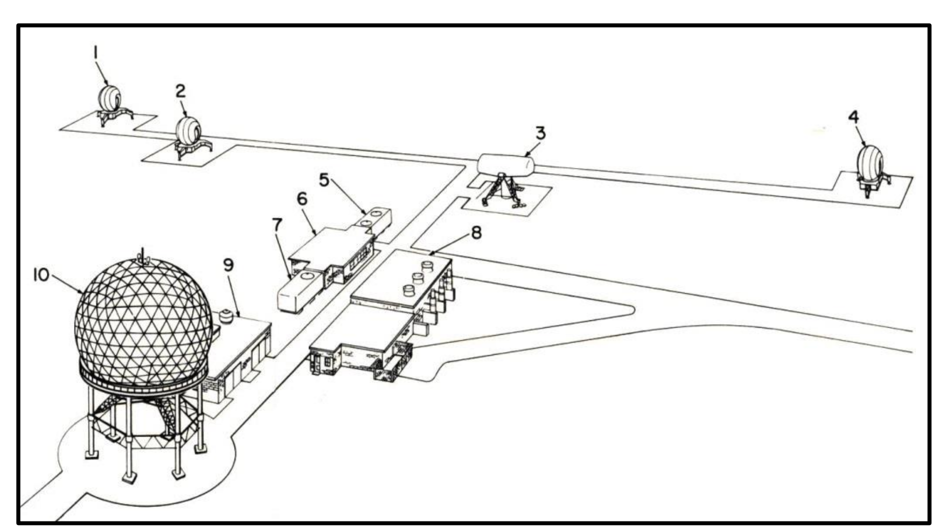
[6] http://www.radartutorial.eu/06.antennas/Monopulse%20Antenna.en.html
[7] http://ed-thelen.org/NikeMissions.html



The main elements of the Nike Hercules Basic variant



Nike Hercules improved



Nike Hercules ATBM

1, TTR, Target Tracking Radar	***2, TRR, Target Ranging Radar***
3, LOPAR (Low Power Acquisition Radar)	***4, MTR, Missile Tracking Radar***
5, Tracking Van	***6, Computer system building***
7, Fire Control Van	***8, Power generator building,***
9, HIPAR (High Power Acquisition Radar) building	***10, HIPAR (High Power Acquisition Radar) antenna***

From 1958 a part of Nike Ajax were upgraded to Hercules, Hercules sites were the followings, the numbers in brackets show the number of SAM sites: [8]

[8] *Rings of Supersonic Steel, chapter 2.*

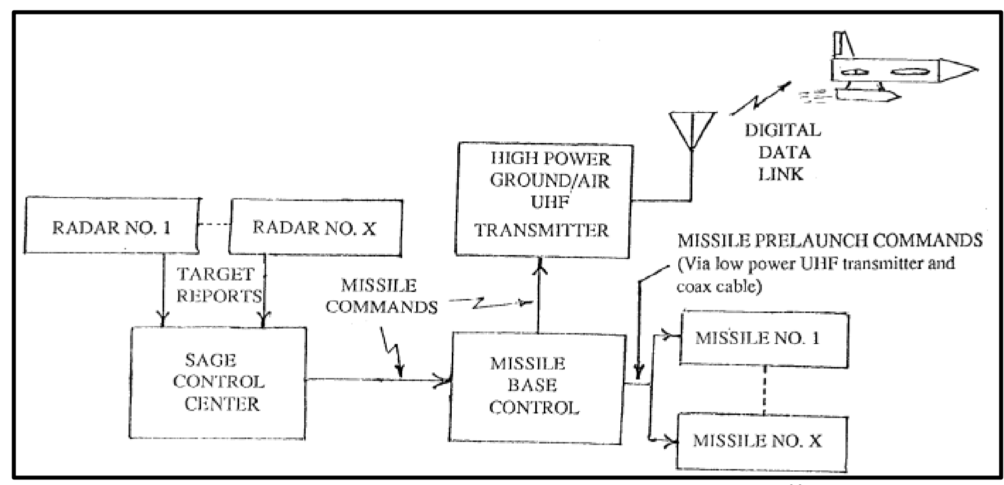
From 1958	***Cities*** Baltimore (5), Boston (3), Bridgeport (1), Buffalo (1), Chicago (9), Cleveland (3), Detroit (6), Hanford (1), Hartford (2), Los Angeles (9), Milwaukee (3), New York (10), Niagara Falls (2),Norfolk (3), Philadelphia (5), Pittsburgh (6), Providence (2), San Francisco (5), Seattle (3), Washington (5). ***Air Force bases*** Ellsworth AFB (1), Fairchild AFB (1), Loring AFB (2), Travis AFB (2). Thule AFB (4
From 1959	Anchorage (3), Fairbanks (5), Kansas (4) Minneapolis (4), all these were new sites.
From 1960	***Cities*** Cincinnati (4), Dallas-Fort Worth (4), St. Louis (4), ***Air Force bases*** Barksdale AFB (2), Bergstrom AFB (2), Dyess AFB (2), Lincoln AFB (2), Offutt AFB (2), Robins AFB (2), Turner AFB (2), Walker AFB - Roswell (2) all these were new sites.
1961	Hawaii (4)
1962	Miami (5)

<u>CIM-10 BOMARC</u>

Besides the two Nike systems USA used another SAM system the BOMARC which was developed by the USAF. This could happen because of the point of view of the Air Force. The USAF treated the missile as pilotless aircraft therefore it got USAF designation either (F-99). Developing of the BOMARC started in 1949 as GAPA (Ground-to-Air Pilotless Aircraft) and later was renamed to BOMARC (BOeing and Michigan Aerospace Research Center). The “interceptor unit” used ramjet rocket engine and was equipped with nuclear warhead or a 450 kg (!) size conventional warhead.[9] The BOMARC had combined guidance in traveling phase used RCG in terminal phase active radar homing (it was first of its kind). The ARH guidance was so inaccurate in that time missiles used the conventional warhead only for tests in war only nuclear warhead would be the only real option. (10 kiloton W-40 nuclear fission warhead)

The engagement zone of the BOMARC was extraordinary large just considering even the very early variants; the final delivered and upgraded variants had range values between 225 and 420 nautical miles (415 km and 785 km.) even at low level engagement profile reached the most advanced version 280 nm (515 km) engagement range.[10] This large EZ was supported by many guidance stations during the mid-course phase the interceptor unit/missile got information from the radars which were part of the SAGE IADS system. This mid-course RCG and many relay stations provided the necessary data to use the large kinematic range of the missile.

[9] *Even the largest Soviet missile the (5V21 of the S-200) had only half of this size.*
[10] *See the sources about the different versions of BOMARC in the attachments.*



The guidance method block scheme of the BOMARC[11]



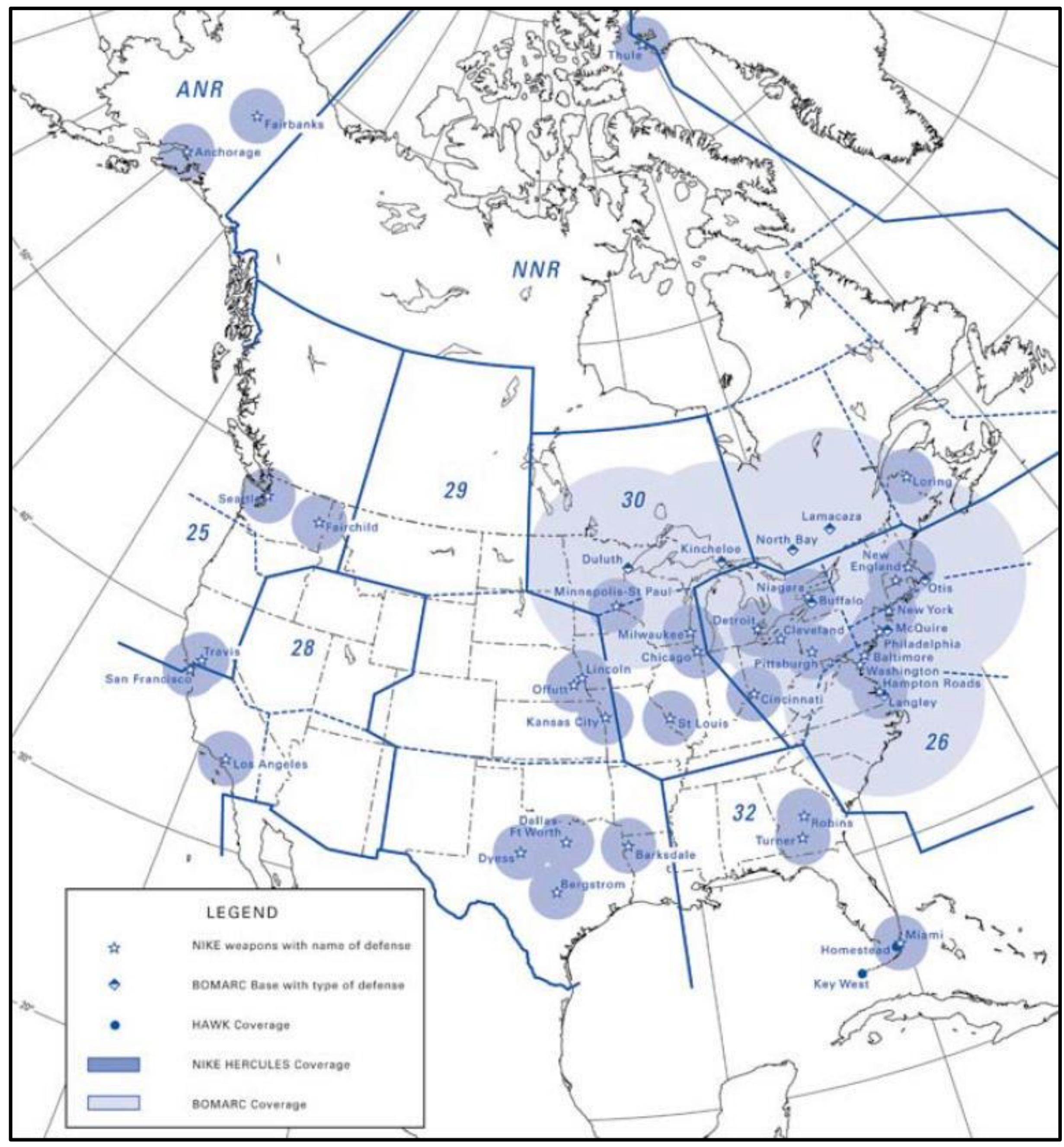
October 1960, BOMARCs in New Jersey (BOMARC Site No. 1)

The interceptor/missile had two stages; the booster stage of CIM-10A missile had LR59-AJ-13 liquid-fuel rocket with 156 kN (35 000 lbf) thrust the traveling stage used 2 pcs RJ43-MA-3 ramjet engine with 51 kN (11 500 lbf) thrust. CIM-10B was different the booster stage was Thiokol M51 solid-fuel rocket with 222 kN thrust (50 000 lbf) and traveling stage had 2 pcs RJ43-MA-7 ramjet with 53 kN (12 000 lbf).

Because of the very large range of the missile relatively few sites were enough to provide real area defense for the most important cities of the US and Canada. Initial plans considered 52 BOMARC sites in the United States with 120 missiles each but at the height of the program only 14 BOMARC sites located in the US (and two in Canada). After knowing the real situation following the "myth busting of the "Bomber gap" the combined firepower of the Nike Hercules and BOMARC was more than enough especially if interceptor fighters are also considered the part of IADS with SAGE. The BOMARC sites could engage incoming bombers with hundreds of missile no matter they arrived from Atlantic Ocean or Polar regions.

The area defense capability of BOMARC was much larger even the later developed Soviet S-200 family but it has to be noted the S-200 family reached the 150, 180, 240 and finally 300 km range with S-200D Dubna variant without using nuclear warhead (was an option for S-200 but was not mandatory.)

[11] http://ss.sites.mtu.edu/mhugl/2017/10/24/raco-aff/



Engagement zones of the Nike Hercules and BOMARC sites

In the footnote are some videos about the development and testing of the BOMARC.[12]

The BOMARC similar to Nike Ajax and Hercules never was used in real combat but it has very bad reputation because of the legends and myths which built around the Canadian developed CF-105 Arrow interceptor fighter. The history of BOMARC and CF-105 is tied because what happened with aviation industry of Canada at late '50s.

In a TV movie[13] the BOMARC was described as an ineffective system while it had only the same issue as the CF-105. The threat simply did not exist when Canada planned to put into service them. From mid '60s USSR have up attacking the CONUS with intercontinental bombers because of the force ration between NORAD and Soviet bombers and in that time hundreds of ICBMs became available.

[12] *https://www.youtube.com/watch?v=uzhkMujY4AQ*
https://www.youtube.com/watch?v=1Fo1DK32lSE
[13] *https://www.imdb.com/title/tt0118641/ The TV movie just boosted more the legends and myths...*

The BOMARC was retired after a very short service because of the same reason why the development and manufacture of the CF-105 it was simply not necessary. The CF-105 vs BOMARC was rather a political than technical debate especially the CIM-10B had only nuclear warhead and Canada was not a nuclear power they had to rely on US. The BOMARC was just is in phase lag as the CF-105.

Shutting down the CF-105 was the right decision because it was as special as the MiG-25 the only possible role which could be imagined for a special variant was high altitude fast reconnaissance but such large as very expensive jets hardly could be exported to anywhere. If the program had not been shut down it would was just a much bigger financial failure. Most of proposed weapons and avionics for CF-105 were on paper or in very early prototype stage. With hindsight we know the ARH guided AAM-N-3/AIM-7B was only a dream a similar AAM could be developed only decades later (AIM-120 AMRAAM.)

About 1000 F-102 Delta Dagger were built and only about 350 F-106 Delta Dart. The trend was clear no more interceptors were needed after ICBMs became available in massive scale. The Canadian high tech aviation industry said “all in” in the poker game of fighter development but the bet was placed on wrong cards. USA after F-106 never developed any dedicated interceptor but its aviation industry survived this change because many other aircraft types were in the portfolio of aviation manufacture companies while the Avro did not have any advanced jet plan.